Purus: The ultraportable climate control device for modern adventurers

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Abstract* — With global temperatures rising to increasingly dangerous levels, poor air quality affecting 91% of the global population and high humidity creating the conditions for poor respiratory health, air conditioning (AC) and purification technologies continue to increase in importance. These problems disproportionately affect people with respiratory problems including asthma and children. While AC solutions exist, there are no backpackable solutions that simultaneously control temperature, humidity and air quality when it comes to spending time outdoors. Purus aims to help people safely enjoy outdoors activities including camping, backpacking and festivals by developing a smart, ultraportable climate control device powered by thermoelectric cooling, dehumidification, and air filtration technology.

I. Introduction / Background

The world Air Quality Index (IQAir) states that 7 million people die every year as a result of exposure to fine particles in polluted air. Air pollution comes from both natural sources, including dust particles, dirt and burning materials, and manmade sources, including combustion, industrial processes, toxic gases and agriculture. Scientists from the Intergovernmental Panel on Climate Change (IPCC) foresee the planet heading for at least 2.5C of heating this century with increases in heatwaves, wildfires and storms (The Guardian, 2024). There were 10 days of extreme humidity across the UK and Europe in 2022 and as our climate warms there are risks we will see increasing instances of overheating issues such as heat exhaustion and heat stress (Willett, 2023). It was reported that this has already resulted in 2,000 heat-related deaths each year **in the UK alone** which could triple by 2050 as the climate warms (BBC, 2022).

Meanwhile, outdoor activity in the UK is skyrocketing, with participation up by 50% since 2017 to 3.86million people in 2022 (Statista, 2022), with 33% of people also describing themselves as an "adventure enthusiast". Research conducted by Deloitte in 2021 also highlighted that 21% of people plan to engage in multi-day activities including camping and trekking meaning that overnight trips in some form of accommodation, such as a tent or caravan, are equally on the rise. This accommodation suffers from challenges related to undesired condensation or "stuffiness", poor ventilation and fluctuating temperatures as well as the potential to build up unwanted odours. With 1 in every 12 adults and 1 in every 11 children having asthma (Asthma + Lunch UK, 2021), this environment can be challenging, particularly for those who want to engage more in outdoor activities. Whilst air conditioning and purification solutions exist, they are bulky, heavy, noisy, complex and bad for the environment (particularly in the case of refrigerant-based and desiccant dehumidifying systems) meaning they're unsuitable for carrying in backpacks on outdoor escapades. Additionally, portable fans have been shown to be ineffective at cooling for temperatures above 35 degrees celsius (Meade et al., 2024).

The thermoelectric effect was discovered in 1834 and thermoelectric technology has been around since the 1940s and thermoelectric generators (TEG) and thermoelectric coolers (TEC) are well researched. Benefits of thermoelectric technologies include: portability, quiet operation, environmentally friendly, lightweight and multifunctionality. On the other hand, they are widely known to be significantly more inefficient than traditional techniques.

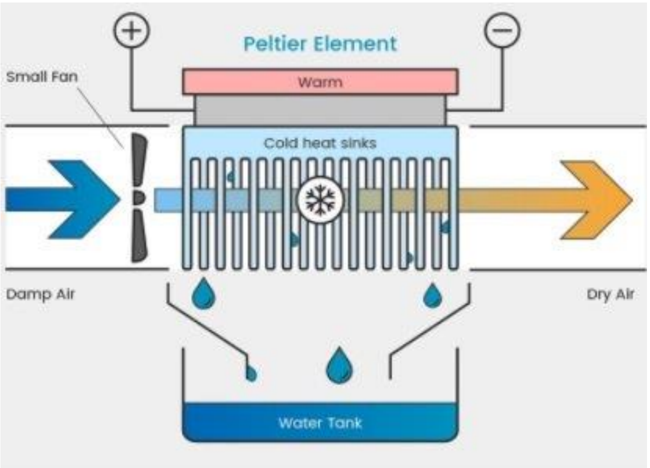


Figure 1 – simplified thermoelectric dehumidification process using a peltier module, heat sink and fan

Thermoelectric dehumidifiers (TED), which are cooling-based, can be a viable alternative to refrigerant-based dehumidifiers in these environments and could be coupled with other air filtration technologies to manage the internal climates of small accommodation spaces including tents, teepees or camper vans. They can operate directly with DC voltage and therefore be powered directly by solar to provide a form of constant climate control for users and be backed up by lithium-ion batteries during night-time. Smart technology allows users to passively and efficiently control conditions based on inputs from sensors which creates further opportunities for optimisation of environmental conditions based on the users desired comfort. The successful integration of this technology to create a smart, ultraportable climate control device and an exploration into the feasibility, viability and desirability of this will be a primary goal of the prototyping process for Purus.

II. Related work

In 3 a new cooling system for a TED was designed and found that higher Coefficient of Performance could be achieved by lowering the drive voltage for the thermoelectric module (a common TEC1-12706) and by drilling 2 holes within the hot side heatsink resulted in a 20% increase in dehumidifying capacity.

In 4 a review of existing TED prototypes and products is conducted and found that the challenges faced by TED performance can be overcome through optimising design and materials selection whilst the heat rejection of the hot side heat sink directly quantifies the cooling capacity for the TED. It also found that hydrophobic paints improved water collection.

Furthermore, in 1 the researchers found that there exists an optimum heat transfer area allocation ratio for achieving the highest COPmax and Qcmax (cooling capacity) meaning that this is also a critical factor in the optimal design of the TED.

2 is a comprehensive optimisation study which looks at the influences of structural parameters as well as layout of TEMs, air duct size, heat sink size and number of TEMs, it found that a larger moisture removal rate can be achieved by 1) preventing frosting through fan speed control, 2) using a smaller cross-sectional area of air duct, 3) using a shorter air duct in summer and longer air duct in winter, 4) sandwiching a pair of TEMs and heat sinks directly opposite to one another.

Whilst the previous works tend to focus on the design, experimentation, analysis and optimisation of key TED parameters (layout, heat sinks, TEM input voltage, input air flow etc.), it is acknowledged in 4 that it is still difficult to precisely control humidity and temperature.

There is limited research into combining TEDs with integrated sensors, control systems and air purification technologies to create a smart, ultraportable climate control device. Using the conclusions of existing works and the integration of new heat sink designs, materials and semiconductor technologies we will create a prototype device, referred to as Purus, that is capable of actively controlling the humidity and temperature of the climate whilst purifying the air within a small accommodation space (e.g. a 3-4 person tent between 150 and 200 cu ft).

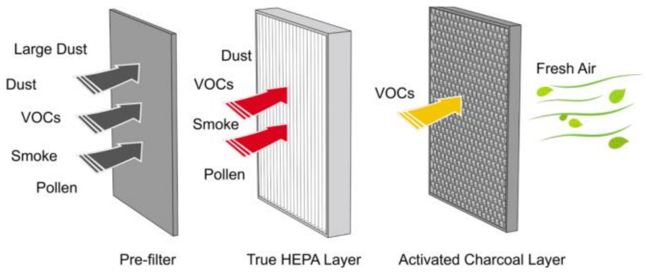


Figure 2 – 3-stage air filtration overview

III. Imagined or existing prototype sketches/drawings/photos

A. *Concept of operation*

Purus is a smart, ultraportable climate control and air purification system for modern adventurers. It operates by first sensing the ambient air of the environment with sensors, processing the data through the control electronics and displaying temperature, humidity and air quality on a display output. The user will then specify a desired humidity and temperature, based on pre-set modes or their specific comfort level, and the system will then adjust the operation to meet that level.

The system will pump humid, dirty air through the pre-filter inflow using an electric fan, this air will then hit the cold side of the TEM which, dependent on the dew point of the air, will begin to form condensate on due to the TEM operation which will then collect in the reservoir. The cool dehumidified air will then pass through a 2-stage filtration process, firstly a true HEPA air filter will filter out 99.97% of particles whose diameter is equal to 0.3µm including pollen, dirt, dust, moisture, bacteria and viruses, which are common problems in nature. The second stage consists of an activated carbon filter that will remove volatile organic compounds (VOCs), smoke from fires or tobacco and neutralise odours. The system will then pump the cooled, dehumidified and purified air out through the outflow using a second electric fan.

As a smart, active system, if turned on and set to a specific level and the environment reaches that level, it will automatically turn off until the ambient air falls outside thresholds that have been set by user (for example throughout the night when sleeping).

B. *Sub-system breakdown*

It is expected that the key elements of the Purus prototype will consist of the following sub-systems:

Sub-System	**Function**
Sensors and electronic control system	Sense air temperature, humidity and quality and control thermoelectric system and display.
Thermoelectric cooling and dehumidification system	Cool and dehumidify air passing through system.
Air filtration and purification system	Filter and purify air passing through system.
Electronic display	Display for power level, temperature, humidity and highlight any issues
Power system	Control charging/discharging of lithium-ion batteries, manage power inputs and power outputs
Air input / output system	Control air inflow and outflow
Structure / housing	Protects device from impacts, moisture ingress, and houses electronics

Reservoir system	Captures moisture from dehumidifier.

C. *Components and materials*

In terms of specific components and materials for the prototype, I expect to utilise the following:

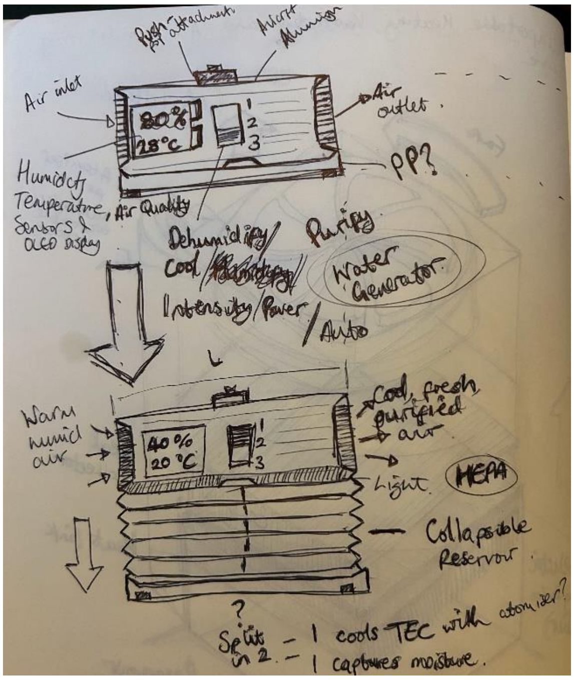
1. 1 x Arduino UNO
2. 1 x Air quality sensor
3. 1 x Temperature and humidity sensor
4. 1 x Thermoelectric module (TEC1-12706)
5. 1 x HEPA filter
6. 1 x Activated carbon filter
7. 1 x OLED display
8. 1 x Aluminium housing
9. 2 x 5V electric fan (>6m3/h)
10. 1 x 33W lithium-ion battery (2S1P x 21700)
11. 1 x USB-C charging circuit
12. 1 x collapsible reservoir (BPA-free silicone)

D. *Method of building*

I expect the approach to building the prototype will be to build the system in modules, however this is something I hope to explore further with support from Pro2 network Summer School.

E. *Early sketches and concepts*

The sketch below highlights key features of an early concept



In terms of early visualisations, I have utilised the help of Midjourney to gather a range of concepts purely for visual and conceptual purposes, in no way do these concepts represent, influence, constrain or limit the final design which will ultimately be determined by feasibility (technical), desirability (customer) and viability (economic) as well as sustainability.

IV. Responsible innovation

Purus directly addresses a challenge that people face when undertaking outdoor pursuits including camping. With global temperatures rising to increasingly dangerous levels, poor air quality affecting 91% of the global population and high humidity creating the conditions for poor respiratory health, air conditioning (AC) and purification technologies continue to increase in importance. These problems disproportionately affect people with respiratory problems including asthma and children. By supporting people with respiratory problems to further engage in outdoor activity which is known to be beneficial for both mental and physical health, this product will add value to society.

In terms of environmental sustainability, whilst not very efficient, thermoelectric devices are sustainable in that they do not produce any tailpipe emissions, are long-lasting, reusable and durable and are simple in operation with no unsustainable complex components (when compared to refrigerant-based and desiccant dehumidifying systems).

There are future possibilities to be explored by integrating technologies including piezoelectric atomisers (for combined humidification/dehumidification) and atmospheric water generation (AWG). This would expand the applications across remote communities, medical, military, disaster and humanitarian aid, field research and remote communities.

V. Author bio(s) / experiences

Samuel is a Product Design Engineer, Founder and UKRI Young Innovator with a background in engineering, technology and design working on projects ranging across naval architecture, design engineering and product design. Samuel is the Founder of Revolv, an outdoor equipment innovation and product development company where our mission is to create regenerative experiences in Nature through developing portable, multifunctional outdoor gear and technology.

An avid outdoorsman, he believes that by encouraging more people to experience Nature through self-driven and shared adventure will we all truly appreciate the beauty of the natural world, be motivated to protect what we have and regenerate what we've lost. He has a NCFE-accredited level 2 Bushcraft Qualification and is working towards his level 3 in Applied Wilderness Skills making him knowledgeable in outdoor pursuits.

As a UKRI Young Innovator, he received £20k in funding and business support to develop as a future leader in innovation encompassing training and development across Leadership and Management, Design Thinking, Product Design, Research, Business Strategy, Entrepreneurship and Innovation.

His skill set consists of:

- Design Thinking,
- Problem Solving,
- Product Design and Engineering,
- Ideation, Sketching + Modelling,
- Team Building and Collaboration,
- Additive Manufacturing,
- Innovation Techniques,
- Hands-on Prototyping,
- Biomimicry,
- Circular Economy.

VI. Acknowledgements

None.

VII. References

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